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The Macrophyte Flora of 46
Acidified and Acid-Sensitive Soft Water Lakes
in Ontario

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INTRODUCTION

Investigations of the biological effects of acidification on fresh waters have focused on phytoplankton (Stokes et al. 1973; Almer et al. 1974; Yan 1979), zooplankton (Sprules 1975; Yan and Strus 1980; Hobaek and Raddum 1980), benthic invertebrates (Raddum 1980; Singer 1981) and fisheries (Beamish and Harvey 1972; Beamish 1974; Lievestad et al. 1976). Studies on the effects of acidification on lake macrophyte floras are limited. Significant increases in littoral zone coverage of the bryophyte Sphagnum spp. with concomittant losses of isoetid vegetation have been documented in acidified lakes in Scandinavia (Grahn 1976; Grahn 1977; Hultberg and Grahn 1976; Hultberg 1977). Dense growths of Sphagnum have also been observed in acidic Colden Lake in the northeastern United States (Hendrey and Vertucci 1980). In Ontario, Gorham and Gordon (1963) investigated differences in flora among 29 acidified, metal-contaminated lakes near Sudbury. Many of these lakes exhibited a marked degree of floristic impoverishment. Species richness was positively correlated with distance of the water body from the smelter complex. The authors hypothesized that metal toxicity rather than acidification was responsible for limiting floristic variety.

In this study we compare the macrophyte floras of 46 soft water lakes from the Sudbury, Killarney, Haliburton, Muskoka and Parry Sound areas of Ontario, with the intent of assessing whether acidification of Ontario lakes alters macrophyte species composition or richness.

DESCRIPTION OF THE STUDY AREA

A total of 46 south-central Ontario lakes located in the Parry Sound, Sudbury, Killarney, Haliburton and Muskoka areas were selected for study (Figure 1). The lakes varied in pH from 3.3 to 7.1 (Table 1). Acidity in two Parry Sound lakes (Axe and Horn) was attributable to humic acids, since field observation indicated the lakes were highly coloured. The low pH of several other study lakes was probably also primarily attributable to humic acids. In the Haliburton and Muskoka areas, the waters of Cinder, Crosson, Fawn, Leech, McKay and Moot Lakes were all highly coloured.

Several of the acidic Haliburton and Muskoka lakes are not coloured, particularly Leonard, Heney and Plastic Lakes, with pH levels of 5.5, 5.5 and 5.2, respectively (Table 1). The low pH of these lakes may, therefore, indicate acidification attributable to acidic precipitation. Ephemeral pH depressions which may cause fish kills have been observed in the area (Jeffries et al. 1979).

Many lakes in the Sudbury and Killarney areas have been acidified by atmospheric deposition of strong acids. The Sudbury area lakes are generally additionally contaminated with trace metals. Extensive morphometric, chemical, biological and hydrological data on these lakes are available (Gorham and Gordon 1963; Dillon _et al_. 1978, 1979; Scheider _et al_. 1979; Yan 1979; Jeffries and Snyder 1981; Miller _et al_. 1983).

METHODS

Field Methods

Divers using snorkelling gear or S.C.U.B.A. examined the littoral zone of each lake and mapped macrophytic vegetation from the shore to the maximum depth of colonization during the summers of 1978 and 1979. All species of submersed and floating-leaved macrophytes were identified. Species composition and a visually estimated percentage bottom coverage were recorded. Water samples for pH determination were collected at a depth of 0.5m in the littoral zone and were analyzed in the field after appropriate meter calibration.

Data Analysis

The following multivariate techniques were used to analyze the data set:

a) DECORANA Analysis

As a first step in analyzing the lake by species data matrix a computer ordination technique called DECORANA (Hill 1979a) was used. DECORANA is an acronym for detrended correspondence analysis. It was derived from a simpler method of ordination called reciprocal averaging (Hill 1973) in an attempt to eliminate the "horseshoe effect" (Kendell 1971) which can distort an ordination on the second and higher level axes.

Any ordination reduces the patterns of species distributions within the lakes to sets of lake scores along several axes. Close proximity of plotted lake scores indicates these lakes have similar communities. If successful, an ordination technique will express most of the variability in the lake by species data on a few, usually less than 4, axes.

As a final step correlations were run between the first axis scores produced by DECORANA and lake concentrations of Cu, Ni, Zn, Mn, Al and H+. Metal levels were taken from Miller *et al*. (1983).

b) TWINSPAN Analysis

The same lake by species presence/absence data set was submitted to a computer classification technique called TWINSPAN (two-way indication species analysis, Hill 1979b). This is a polythetic diversive technique designed to classify into similar groups first the lakes and then the species most indicative of the resultant groups. The final two-way classification table can be used to identify not only which lake floras are responding to particular environmental influences but also which species are generally most tolerant or intolerant of these conditions.

The algorithm for this procedure is complex and is best described in the TWINSPAN manual (Hill 1979b). In essence, a series of divisions are made starting first with the first axis ordination of DECORANA . Each dichotomy is based on the distribution of "differential species". These are defined as species with a clear "ecological preference" to a set of lakes. By this technique a classification of the lakes is completed. Then the species are classified using their preferences to one or the other of the major lake groups as attributes. The final result is an ordered two-way classification table called the refined ordination.

As an aid to interpreting this ordination another step is added. An indicator ordination is constructed using the most strongly differential species to reproduce the dichotomies suggested in the refined ordination. This analysis indicates which lakes score strongly to either side of the divisions and which lakes are "borderline". Occasionally this technique fails to place a lake on the same side of the division as the refined ordination. In such cases the lake is considered "misclassified".

The indicator ordination also presents an analysis of species distributions for all species with at least a 20% occurrence in the parent group. Species are either positive or negative "preferential" if they are twice as likely to occur on a given side of the division. Alternately, they may be "non-preferential" to either side.

The nomenclature used to describe groups produced by this analysis is as follows. The first two groups are designated *0 and *1. The latter group would then be divided into *00 and *01 and so on in this manner. Thus, the groups designation indicates both its origins and at which level of the analysis it was produced.

RESULTS AND DISCUSSION

The Macrophyte Flora

Hitchin (1983) presents abundance and vertical distribution of species in all study lakes. Macrophyte taxa identified in the 46 study lakes are listed in Tables 2, 3 and 4. Generally, lakes in the Muskoka, Haliburton and Parry Sound area (Table 2) supported a flora with species richness comparable to other soft water lakes in Ontario (Miller 1977) and elsewhere (Moeller 1978). The notable exception was Solitaire Lake which was characterized by a highly impoverished flora of only 6 different species. Reasons for the paucity of vegetation in this lake are not clear.

Many of the Killarney Lakes were acidic (Table 1). Despite this, the floras of the lakes were generally as rich (average of 24 taxa per lake) as observed in the non-acidic study lakes in Haliburton, Muskoka and Parry Sound (average of 18 taxa per lake, Table 2). Clearly acidification of these lakes has not had a major detrimental impact on species richness.

In contrast to the two previous groups of lakes, most lakes in the Sudbury area (Table 4) were floristically impoverished, typically supporting less than 10 plant species. In a previous survey of Sudbury area lakes, Gorham and Gordon (1963) found that macrophyte species richness was positively related to the distance of the water body from a local smelting complex and inversely corelated with sulphate concentrations in lake waters. They hypothesized that sulphate concentrations were unlikely to be toxic and attributed the floristic impoverishment to elevated concentrations of heavy metals. Certainly, the paucity of vegetation in Sudbury area lakes, when compared to the rich flora in acidified Killarney area lakes, is consistent with this hypothesis. Levels of Cu and Ni are elevated in lakes in the immediate Sudbury area but decrease very rapidly with distance from the city (Dillon *et al*. 1979).

Vegetation in the 46 study lakes was dominated by rosette or isoetid species which characterize soft water lakes in Europe and North America (Moyle 1945; Sculthorpe 1967; Hutchinson 1975; Moeller 1975, 1978). *Eriocaulon septangulare* typically dominated the flora in most study lakes, except in some Sudbury area lakes where it was supplanted by *Eleocharis acicularis*. This latter specie is extremely tolerant of environmental acidity (Erle 1960). Other common isoetids found in most lakes included *Lobelia Dortmanna*, *Lycopus* sp., *Sparganium* sp. and *Juncus* spp.

Fontinalis antipyretica and Drepanocladus exannulatus were the most ubiquitous bryophytes, occurring in 30 and 13 lakes, respectively. The former specie characterized most lakes in the Muskoka, Haliburton and Parry Sound areas, whereas Drepanocladus was more common in the Sudbury area. The latter specie is generally regarded as more acidophilous than Fontinalis (Sorenson 1948; Malme 1978).

The bryophyte Sphagnum spp. was found in 22 lakes with pH values ranging from 4.0 to 6.8 (Table 5). This moss has been implicated in major floristic changes in acidified lakes in Sweden (Grahn et al. 1974; Hultberg and Grahn 1975; Grahn 1976). For example in Lake Orvattnet, Sweden, Sphagnum coverage in shallow littoral zones increased from 8% in 1967 to 63% in 1974, concomittant with a reduction in lake pH of 0.8 units. Changes of this magnitude were not apparent in the present study. In fact, distribution of Sphagnum was largely localized, ranging from isolated fragments to small pure stands. Extensive growths were found only in a few of the lakes with pH values <5.5 particularly in Terry, Horn, Fawn, George and Carlyle Lakes. In George, Carlyle and Terry Lakes, dense beds of Sphagnum occupied deep waters, whereas in Horn and Fawn Lakes, two lakes with very coloured waters, dense beds were found in shallow littoral areas. There was no visual evidence to suggest that Sphagnum had replaced native isoetid species. Rather, the bryophyte seemed to occupy niches unfavourable for colonization by rosette species, namely, highly organic substrates or deep waters. In fact, the occurrence of Sphagnum in the study lakes is more typical of its distribution in oligotrophic lakes in Norway. Malme (1978) found varying amounts of Sphagnum in 17 of 23 Norwegian lakes with pH values ranging from 5.2 to 7.2 and including several humic lakes.

Multivariate Vegetation Analysis

Ordination analysis typically produces one of three basic configurations. The data points may be scattered along an axis, clustered in two or more distinct groupings or a few points may be separate from a main cluster or clusters. Ordination techniques are most powerfully used on data sets which manifest the first configuration. This configuration indicates a continuous gradient of change (variation) in the data, thus allowing possible correlation with an external continuous variable. Two clusters of points indicate distinct types or groups in a data set and can also be readily interpreted. The third configuration, is of little use in a multivariate analysis since it indicates that 1 or a few points (ie. 1 or a few lakes) are markedly different.

DECORANA Analysis

The first three axis produced by DECORANA ordination are presented in Table 6. Inspection of the first axis indicates that the lakes score along all portions of the axis, although there are fewer near the higher end of the scale, indicating a strong, continuous gradient in the data set. The top lakes on the first axis are all Sudbury area, metal contaminated lakes. The second axis separates Kramer and Labelle Lakes by 25% of the axis from the central cluster of lakes, and places Little Otter Lake at the other extreme. In this case no gradient is evident but rather the analysis is identifying lakes with unique floras and separating them from the central cluster. Examination of the species ordination (Tables 7 and 8) shows that separation of these lakes from the main cluster was based on the presence of 3 rare elements of their floras. Kramer Lake and Labelle Lake were separated because they contained Utricularia cornuta. On the other hand, Potamogeton Vaseyi and Callitriche sp. occurred only in Little Otter and thus caused its ordination score.

The third axis separates Harp Lake from the central cluster. At this level the ordination is identifying the species differences of only one lake and is of little use, in consequence.

Thus, only the first axis contains information which can be meaningfully interpreted in terms of environmental data. Beyond this level of analysis, the lakes are very similar, differing only in the rarer elements of their floras.

Correlation Analysis

Correlation coefficients calculated between the first axis and H+ and metal levels of lake waters were significant ($p<0.05$) for Ni ($r=0.59$), Mn ($r=0.58$) and H^+ ($r=0.47$), but not for Cu, Zn or Al, suggesting a relationship between the floristic ordination and environmental disturbance caused by smelter activity. The correlations do not distinguish whether metals or pH are most important in distorting the floras. However, a plot of pH vs. the first axis (Figure 2) indicates that pH can be discarded as a major cause of floristic disturbance. Acidified lakes (those with pH 5.2) occur all along the first axis. It is only the absence of non-acidified lakes at the higher end of the axis that makes the H^+ correlation significant. It is an unavoidable complication in the data set that acidic lakes in the Sudbury area were also metal-contaminated.

TWINSPAN Analysis

The DECORANA analysis showed a continuous gradient of lakes, rather than discrete groupings, with considerable homogeneity beyond the first axis. The TWINSPAN analysis was used on the data matrix to obtain a classification and characterization of species distribution.

The first division of the data set separated three floristically impoverished Sudbury area lakes (*1) as dissimilar from the main group of lakes (*0) (Table 9). Both *Pohlia nutans* and *Cladopodiella fluitans* were selected as preferential plant species for this (*1) group of lakes (Table 10). The former plant specie occurred exclusively in these three lakes, however, both species must be regarded as highly tolerant of the acidified, metal contaminated conditions. Similarly, the six species listed as non-preferential (Table 10) to the division can be regarded as tolerant of those conditions.

The second division of the ordination (Table 11) separated the remaining 43 lakes into one group of 13 lakes (*00) and a second group of 30 lakes (*01). The latter group had 28 preferential plant species (Table 12) while the first group of lakes had only one preferential specie, namely *Utricularia cornuta*. Eight species were listed as non-preferential to the second division.

The lakes of the larger group (*01) had an average of 21 plant species each, a number comparable to the average flora size indicated by Miller (1977). This probably represents typical conditions for soft water lakes of Ontario.

The paucity of preferential plant species for the smaller group of lakes (*00) suggests that this group is floristically impoverished and has few unique elements to distinguish it. In fact, this group averaged only 8 plant species per lake and is therefore more similar to the 3 Sudbury lakes (*1) than to the typical soft water floras of *01. It is therefore not surprising that 9 of the 13 lakes are from the Sudbury area and contain elevated levels of Cu and Ni.

One notable observation about group *00 is the absence of the bryophyte Sphagnum, found in only one (Kramer Lake) of the thirteen lakes. On the other hand, Sphagnum was present in 60% of group *01 lakes which have been previously described as typical soft water lakes.

In summary, the TWINSPAN analysis divides the 46 lakes into 3 groups. The largest group of 30 lakes consists of essentially undisturbed soft water lakes. The other two groups represent two levels of floristic impoverishment due predominantly to smelter activities of the Sudbury area. The smaller of these two groups (*1) consisted of 3 lakes, all floristically very impoverished and containing Pohlia nutans. The other group (*00) of 13 lakes was also floristically impoverished and contained no distinguishing or unifying plant species.

CONCLUSIONS

1) Lakes from the Muskoka, Haliburton and Killarney regions generally contained floras regarded as typical of undisturbed soft water lakes in Ontario and elsewhere. Acidic, metal-contaminated Sudbury area lakes, in comparison were floristically impoverished.

2) The bryophyte Sphagnum was found in 22 of the 46 study lakes at pH values ranging from 4.0 to 6.8. In Sweden, Sphagnum has increased in abundance with progressive acidification, with concomittant loss of isoetid floras. Similar perturbations were not evident in the present study, Sphagnum occupied niches unsuitable for isoetid colonization and was generally absent from acidified Sudbury area lakes.

3) The first axis of the DECORANA analysis correlated with Ni, Mn and H^+ concentrations in lake waters, suggesting that smelting activities in the Sudbury area has affected lake floras. It appears that metal contamination of these lakes is more significant than pH in distorting macrophyte floras since low pH lakes which are not metal contaminated are rarely floristically impoverished.

4) TWINSPAN analysis indicated that variation in the data set was primarily influenced by species richness rather than species change. Of the 3 groups of lakes delineated by the analysis, the largest group of lakes contained typical soft water floras, a second group was impoverished and a third group was highly impoverished with one unique plant specie.

5) *Pohlia nutans*, *Cladopiella fluitans*, *Sparganium* sp, *Eleocharis acicularis*, *Nuphar variaegatum*, *Sagittaria* sp. *Juncus peleocarpus* and *Drepanocladus exannulatus* were considered to be highly tolerant of metal contaminated, acidified conditions.

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TABLE 1: Location of study lakes. Identification codes used in Figure 1 are indicated. Measured lake pH levels are included.

Region	Code	Lake	Township	pH
Parry Sound	1	Axe	Monteith	4.4
	29	Horn	Monteith	4.2
	34	Little Otter	Foley	6.5
	40	Otter	Foley	6.4
Sudbury	8	Clearwater	Tilton & Broder	4.4
	15	Gorham & Gordon #4	Garson	5.1
	16	Gorham & Gordon #8	Garson	3.3
	17	Gorham & Gordon #14	Garson	3.9
	18	Gorham & Gordon #21	Broder	5.5
	19	Gorham & Gordon #54	Snider	4.7
	20	Gorham & Gordon #75	Cleland	5.2
	21	Gorham & Gordon #94	Dowling	5.7
	22	Gorham & Gordon #103	Moncrieff	6.0
	24	Hannah	Broder	7.1
	35	Lohi	Broder	4.8
	37	Middle	Broder	6.5
	39	Nelson	Bowell	6.4
	44	Swan	Broder	3.9
	46	Labelle	Lumsden	6.3
Killarney	2	Bell	Groschen	4.8
	4	Carlyle	Carlyle	4.6
	12	Freeland	Killarney	4.3
	13	Frood	Curtin	6.6
	14	George	Killarney	4.8
	30	Kramer[1]	Curtin	4.0
	45	Terry	Carlyle	4.5
Haliburton and Muskoka	3	Brandy	Monck & Watt	6.4
	5	Chub	Ridout	6.2
	6	Cinder	Hindon	5.3
	7	Clear	Oakley	6.4
	9	Crosson	Oakley	5.3
	10	Dickie	McLean	6.0
	11	Fawn	Macaulay & Stephenson	5.3
	23	Gullfeather	Oakley	5.8
	25	Harp	Chaffey	6.8
	26	Healey	Macauley	5.6
	27	Heney	McLean	5.5
	28	Hillman	Monck	6.3
	31	Leech	Oakley	5.2
	32	Leonard	Monck	5.5
	33	Little Clear	Clyde	6.9
	36	McKay	Draper	5.6
	38	Moot	McLean	5.9
	41	Plastic	Sherborne	5.2
	42	Red Chalk	Ridout	6.6
	43	Solitaire	Sinclair	7.0

1-unnamed lake identified by principle investigator's name

TABLE 2: Flora of Parry Sound, Muskoka and Haliburton area lakes. Asterisk indicates occurrence of species. Lake name codes indicated in Table 1.

TAXON	LAKE NAME CODES																						
	3	5	6	7	9	10	11	23	25	26	27	28	31	32	33	36	38	41	42	43	1	29	34	40
Nitella resupinata var acuminata A.Br. ex Wallm.												*												
Nitella flexilis (L.)Ag.	*						*		*						*	*								
Nitella furcata (Roxb.ex Bruz)Ag.																							*	*
Nitella gracilis (Sm.)Ag.											*													
Nitella tenuissima (Desv.) Kutz	*	*					*				*												*	*
Chara spp.												*												
Eleocharis acicularis (L.)R.&S.	*			*	*	*	*	*	*	*	*		*	*	*	*	*	*	*		*	*	*	*
Eleocharis Robinsii Oakes					*						*					*	*							*
Eriocaulon septangulare With.	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		*	*
Pontederia cordata L.	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		*	*	*	*
Juncus militaris Bigelow			*		*	*	*	*		*	*	*				*		*			*	*	*	*
Juncus peleocarpus E. Meyer	*			*		*	*		*	*	*	*	*	*	*	*			*	*	*		*	*
Brasenia Schreberi Gmel.	*	*	*	*	*	*	*	*	*	*	*	*				*			*		*	*		
Nuphar variegatum Engelm.	*	*	*	*	*	*	*	*				*	*	*	*	*	*	*			*	*		*
Nymphaea odorata Ait.	*	*	*		*	*	*	*	*	*	*	*				*		*	*		*	*	*	*
Ranunculus reptans L.																							*	*
Callitriche spp.																							*	
Elatine minima (Nutt.)Fisch. & Meyer	*			*		*												*		*			*	*
Isoetes spp.	*	*		*	*	*	*	*	*	*	*		*	*	*	*	*	*		*			*	*
Sparganium spp.		*	*	*	*	*	*	*	*	*	*		*	*	*	*	*	*				*		*
Myriophyllum Farwellii Morong			*																					
Myriophyllum heterophyllum Michx.			*																					
Myriophyllum humile (Raf.)Morong			*																					
Myriophyllum tenellum Bigelow						*		*		*	*	*	*	*	*	*	*	*	*		*			*
Najas flexilis (Willd.)R.&S.	*										*	*	*										*	
Sagittaria spp.	*						*																*	*
Vallisneria americana Michx.	*						*			*					*	*							*	
Potamogetan amplifolius Tuckerm.												*												
Potamogetan Berchtoldii Fieber		*									*													*
Potamogetan capillaceus Poiret							*				*						*							*
Potamogetan confervoides Reichenb.										*	*					*					*			
Potamogetan epihydrus Raf.	*	*			*	*	*	*	*	*	*	*	*		*	*	*	*			*	*	*	*
Potamogetan foliosus Raf.																						*		
Potamogetan natans L.			*		*		*	*	*		*					*					*	*		*
Potamogetan Oakesianus Robbins.		*					*	*			*			*		*					*	*		

TABLE 2: (cont'd.) Flora of Parry Sound, Muskoka and Haliburton area lakes. Asterisk indicates occurrence of species. Lake name codes indicated in Table 1.

TAXON	LAKE NAME CODES																							
	3	5	6	7	9	10	11	23	25	26	27	28	31	32	33	36	38	41	42	43	1	29	34	40
Potamogetan obtusifolius Mert. & Koch.												*												
Potamogetan pusillus L.											*	*				*								
Potamogetan Robinsii Oakes												*											*	
Potamogetan Vaseyi Robbins																							*	
Nymphoides cordatum (Ell.) Fernald.		*								*	*			*							*			
Utricularia gibba L.							*				*										*			
Utricularia intermedia Hayne										*		*									*			*
Utricularia minor L.						*																		
Utricularia purpurea Walt.		*	*		*	*				*	*	*		*	*			*	*		*		*	*
Utricularia resupinata B.D. Greene	*	*		*	*	*	*	*		*	*	*	*	*		*	*	*	*		*			*
Utricularia vulgaris L.			*		*	*		*	*	*	*	*	*		*		*	*	*		*	*	*	*
Lobelia Dortmanna L.		*		*	*	*		*	*	*	*		*	*	*	*	*	*	*	*	*		*	*
Lycopus spp.		*	*		*	*	*	*			*		*	*	*	*	*		*			*	*	*
Fissidens fontanus (B.-Pyl)Steud.							*																	
Drepanocladus spp.													*								*	*		
Eurhynchium riparioides (Hedw.)Rich.									*															
Fontinalis antipyretica Hedw.									*				*	*	*		*		*	*				
Fontinalis durlaei Schimp.																*							*	
Fontinalis hypnoides var durlaei F.					*																			
Fontinalis nova-angliae Sull.																*								
Fontinalis spp.	*	*	*	*	*	*	*	*		*	*					*		*			*	*	*	
Sphagnum cuspidatum Ehrh. ex Hoffm.				*			*			*						*					*	*		
Sphagnum palustre L.				*																				
Sphagnum subsecundum var contortum (Schultz)Hub.			*					*																*
Sphagnum subsecundum var innundatum (Russ.)C. Jens.			*																					
Sphagnum subsecundum var platyphyllum (Lindb.ex Braithw.)Card				*			*									*		*				*		*
Sphagnum subsecundum var subsecundum Nees ex Sturm						*																		
Sphagnum spp.		*						*			*											*		
Mnium psuedopunctatum Hedw.						*																		
TOTAL TAXA	17	18	17	16	19	19	25	19	18	21	30	20	17	17	16	27	15	18	13	6	23	19	24	28

TABLE 3: Flora of the Killarney area lakes. Lake name codes indicated in Table 1.

TAXON	LAKE NAME CODE						
	2	4	12	13	14	30	45
Nitella flexilis (L.)Ag.				*			
Nitella tenuissima (Desv.) Kutz				*			
Chara spp.				*			
Eleocharis acicularis (L.)R.&S.	*	*	*	*	*		
Eleocharis Robbinsii Oakes	*	*		*			
Eriocaulon septangulare With.	*	*	*	*	*		*
Pontederia cordata L.	*	*	*	*	*		*
Juncus militaris Bigelow	*	*	*	*			*
Juncus pelocarpus Meyer	*	*		*	*		
Polygonum natans Eaton				*			
Ceratophyllum demersum L.				*			
Brasenia Schreberi Gmel.	*	*	*	*	*		*
Nuphar variegatum Engelm.	*	*	*	*			*
Nymphaea odorata Ait.	*	*	*	*	*	*	
Ranunculus reptans L.		*		*	*		
Elatine minima (Nutt.)Fisch. & Meyer		*		*	*		
Isoetes spp.	*	*	*	*	*		*
Sparganium spp.	*	*	*	*	*		*
Myriophyllum alterniflorum D.C.				*			
Myriophyllum Farwellii Morong.	*	*		*	*		
Myriophyllum tenellum Bigelow	*	*		*	*		
Najas flexilis (Willd.)R.&S.				*			
Sagittaria spp.	*	*		*	*		*
Elodea canadensis Michx.				*			
Vallisneria americana Michx.	*			*			
Potamogeton amplifolius Tuckerm.				*			
Potamogeton Berchtoldii Fieber	*			*			
Potamogeton capillaceus Poiret	*			*			
Potamogeton confervoides Reichenb.	*	*	*		*		*
Potamogeton epihydrus Raf.	*	*	*	*	*		*
Potamogeton foliosus Raf.	*			*			
Potamogeton natans L.	*		*	*			
Potamogeton Oakesianus Robbins.			*				
Potamogeton obtusifolius Mert. & Koch.				*			
Potamogeton Richardsonii (Benn.)Rydb.				*			
Potamogeton Spirillus Tuckerm.				*			
Nymphoides cordatum (Ell.)Fernald.	*	*		*			*
Utricularia cornuta Michx.						*	
Utricularia gibba L.				*			
Utricularia intermedia Hayne				*			
Utricularia purpurea Walt.	*	*	*	*	*		*
Utricularia resupinata B.D. Greene	*	*					
Utricularia vulgaris L.	*	*	*	*	*	*	*
Lobelia Dortmanna L.	*	*		*	*		
Lycopus spp.	*	*	*	*	*	*	*
Gymnocolea inflata (Huds.)Dum.	*						
Cladopodiella fluitans (Nees)Buch.							*
Drepanocladus exannulatus (BSG)Warnst.		*					
Drepanocladus spp.	*			*			
Fontinalis duriaei Schimp.		*					
Fontinalis spp.	*			*	*		*
Sphagnum cuspidatum Ehrh. ex Hoffm.	*	*					
Sphagnum majus. (Russ.)C.Jens.	*						
Sphagnum pylaesii G.G.H.		*					
Sphagnum subsecundum var contortum (Schultz)Hub.		*	*				*
Sphagnum subsecundum var platyphyllum (Lindb.ex.Braithw.)Card.	*				*		
Sphagnum subsecundum var subsecundum Nees ex Sturm		*					
Sphagnum teres (Schimp.)Angstr.ex Hartm.					*		
Sphagnum spp.	*					*	*
TOTAL TAXA	34	30	17	43	22	5	18

TABLE 4: Flora of the Sudbury area lakes. Lake name codes as in Table 1.

TAXON	LAKE NAME CODE														
	8	24	35	37	39	44	46	15	16	17	18	19	20	21	22
Nitella flexilis (L.)Ag.							*								
Nitella tenuissima (Desv.) Kutz														*	
Eleocharis acicularis (L.)R.&S.	*	*	*	*	*	*		*	*		*	*	*	*	*
Eleocharis Robinsii Oakes			*												
Eriocaulon septangulare With.	*	*	*	*	*		*				*		*	*	*
Pontederia cordata L.													*		
Juncus militaris Bigelow					*										*
Juncus pelocarpus E. Meyer	*	*	*	*	*			*				*			*
Brasenia Schreberi Gmel.														*	
Nuphar variegatum Engelm.								*			*		*	*	*
Nymphaea odorata Ait.													*	*	*
Isoetes spp.		*			*								*	*	*
Sparganium spp.								*		*			*	*	*
Myriophyllum Farwellii Morong							*								*
Myriophyllum tenellum Bigelow	*		*		*								*	*	*
Sagittaria spp.		*		*	*	*								*	*
Potamogeton epihydrus Raf.													*	*	*
Potamogeton natans L.							*								*
Potamogeton Spirillus Tuckerm.														*	
Utricularia cornuta Michx.							*								
Utricularia gibba L.														*	*
Utricularia intermedia Hayne															*
Utricularia purpurea Walt.														*	*
Utricularia resupinata B.D. Greene		*													
Utricularia vulgaris L.	*		*			*								*	*
Lobelia Dortmanna L.					*		*							*	*
Lycopus spp.	*													*	
Fissidens fontanus (B.-Pyl)Steud.					*										
Pohlia nutans var schimperii (C.D.S.)								*		*		*			
Cladopodiella fluitans (Nees)Buch.	*							*		*		*			
Drepanocladus aduncus (Hedw.)Warnst.		*	*												
Drepanocladus exannulatus (B.,S,& G.) Warnst.	*							*					*	*	*
Drepanocladus spp.								*							
Fontinalis duriaei Schimp.													*		
Fontinalis nova-angliae Sull.													*		
Fontinalis spp.														*	
Sphagnum cuspidatum Ehrh.ex Hoffm.													*		
Sphagnum palustre L.														*	
Sphagnum subsecundum var platyphyllum (Lindb.ex Braithw.)Card.													*	*	
TOTAL TAXA	8	7	7	4	9	2	6	8	1	3	3	4	14	21	19

TABLE 5: Occurrence of *Sphagnum* SPP. in study lakes

pH	LAKE	REMARKS
4.0	Kramer	Solitary strands
4.2	Horn	throughout lake, several heavy beds to 50% B.C. (bottom cover) over large areas (0-2.0 m)
4.3	Freeland	Solitary strands
4.4	Axe	Solitary strands
4.5	Terry	very heavy beds in deeper water (3-7m) to 100% B.C. over large areas
4.6	Carlyle	throughout lake, mixed stands to 30% B.C. over large areas (1-10m)
4.8	Bell	small clumps, one heavy patch
4.8	George	very heavy beds to 90% B.C. in deeper waters (6-11m) with growth to 18m
5.2	Plastic	one heavy patch
5.3	Fawn	extensive coverage in one bay only to 60% B.C. (0-1m)
5.3	Cinder	small clumps and one heavy patch
5.5	Leonard	solitary strands
5.5	Heney	one heavy patch
5.6	McKay	several small clumps
5.6	Healey	solitary strands
5.8	Gullfeather	solitary strands
6.2	Chub	solitary strands
6.4	Otter	solitary strands and small clumps
6.4	Clear	solitary strands amd small clumps
5.2	G.&G.75	solitary strands
5.7	G.&G.94	solitary strands
6.8	Harp	solitary strands

TABLE 6 Results of the Decorana lake ordination. Lakes are listed according to their ranking along the axes. G and G refers to a Gorham and Gordon Lake.

AXIS 1			AXIS 2			AXIS 3		
Lake No.	Lake Name	Axis Score	Lake No.	Lake Name	Axis Score	Lake No.	Lake Name	Axis Score
17	G & G 14	424	34	Littleotter	265	25	Harp	185
19	G & G 54	332	24	Hannah	223	23	Gullfeather	110
15	G & G 04	280	43	Solitaire	222	43	Solitaire	107
37	Middle	219	3	Brandy	211	45	Tower	105
8	Clearwater	214	37	Middle	209	12	Freeland	104
16	G & G 08	211	16	G & G 8	196	7	Clear	103
44	Swan	200	39	Nelson	190	11	Fawn	98
18	G & G 21	172	19	G & G 54	183	3	Brandy	96
35	Lohi	153	40	Otter	175	6	Cinder	95
24	Hannah	144	41	Plastic	173	42	Red Chalk	93
45	Terry	143	44	Swan	173	33	Little Clear	93
39	Nelson	138	32	Leonard	164	18	G & G 21	92
20	G & G 75	126	14	George	163	16	G & G 8	90
31	Leech	126	10	Dickie	160	5	Chub	88
33	Little clear	114	33	Little Clear	154	28	Hillman	88
32	Leonard	112	4	Carlyle	152	24	Hannah	87
7	Clear	105	15	G & G 04	151	41	Plastic	86
14	George	105	42	Red Chalk	151	36	McKay	84
43	Solitaire	105	7	Clear	150	10	Dickie	82
10	Dickie	104	36	McKay	149	31	Leech	81
38	Moot	104	5	Chub	148	39	Nelson	80
25	Harp	101	31	Leech	148	27	Heeney	78
21	G & G 94	99	27	Heeney	145	32	Leonard	77
22	G & G 103	94	18	G & G 21	144	37	Middle	77
23	Gullfeather	92	38	Moot	143	9	Crosson	75
36	McKay	92	9	Crosson	142	29	Horn	75
4	Carlyle	91	45	Terry	141	34	Little Otter	74
12	Freeland	90	11	Fawn	138	21	G & G 94	73
29	Horn	90	28	Hillman	134	19	G & G 54	72
41	Plastic	88	23	Gullfeather	130	20	G & G 75	72
42	Red Chalk	86	20	G & G 75	127	38	Moot	69
2	Bell	83	26	Healey	126	26	Healey	61
6	Cinder	82	21	G & G 94	122	45	Terry	56
9	Crosson	81	22	G & G 103	117	40	Otter	55
26	Healey	81	12	Freeland	116	1	Axe	51

TABLE 6 (cont'd.) Results of the Decorana lake ordination. Lakes are listed according to their ranking along the axes. G and G refers to a Gorham and Gordon Lake.

AXIS 1			AXIS 2			AXIS 3		
Lake No.	Lake Name	Axis Score	Lake No.	Lake Name	Axis Score	Lake No.	Lake Name	Axis Score
1	Axe	79	25	Harp	111	8	Clearwater	51
11	Fawn	79	2	Bell	107	44	Swan	49
3	Brandy	72	8	Clearwater	107	22	G & G 103	46
40	Otter	72	13	Frood	99	17	G & G 14	40
5	Chub	71	6	Cinder	90	14	George	38
27	Heeney	65	17	G & G 14	86	15	G & G 4	30
30	Kramer	58	1	Axe	83	30	Kramer	27
46	Labelle	29	29	Horn	80	35	Lohi	26
34	Little Otter	28	35	Lohi	65	13	Frood	20
13	Frood	20	30	Kramer	0	2	Bell	7
28	Hillman	0	46	Labelle	0	4	Carlyle	0

TABLE 7: Codes for taxa used in Decorana analysis

	TAXON		TAXON		TAXON
Code	Name	Code	Name	Code	Name
1	Chara sp.	31	Juncus militaris	61	Sphagnum recurvum amblyphyllum
2	Nitella acuminata	32	Juncus pelocarpus	62	Sphagnum teres
3	Nitella flexilis	33	Polygonum amphibium	63	Fissidens fontanus
4	Nitella furcata	34	Cerataphyllum demersum	64	Pohlia nutans schimperii
5	Nitella gracilis	35	Brasenia Shreberi	65	Calliergon giganteum
6	Nitella tenuissima	36	Nuphar variegatum	66	Drepanocladus sp.
7	Isoetes sp.	37	Nymphaea odorata	67	Eurhynchium ripariodes
8	Sparganium sp.	38	Ranunculus reptans	68	Hygroamblystegium tenax
9	Potamogeton amplifolius	39	Collitriche sp.	69	Fontinalis antipyretica
10	Potamogeton Berchtoldii	40	Elatine minima	70	Fontinalis spp.
11	Potamogeton capillaceus	41	Myriophyllum alterniflorum	71	Fontinalis nova-angliae
12	Potamogeton confervoides	42	Myriophyllum Farwellii	72	Cladopodiella fluitans
13	Potamogeton epihydrus	43	Myriophyllum heterophyllum	73	Mnium ellipticum
14	Potamogeton foliosus	44	Myriophyllum tenellum	74	Gymnocolea inflata
15	Potamogeton natans	45	Nymphoides. cordatum		
16	Potamogeton Oakesianus	46	Utricularia cornuta		
17	Potamogeton obtusifolius	47	Utricularia gibba		
18	Potamogeton pusillus	48	Utricularia intermedia		
19	Potamogeton Richardsonii	49	Utricularia minor		
20	Potamogeton Robinsii	50	Utricularia purpurea		
21	Potamogeton Spirillus	51	Utricularia resupinata		
22	Potamogeton Vaseyi	52	Utricularia vulgaris		
23	Najas flexilis	53	Lobelia Dortmanna		
24	Sagittaria sp.	54	Lycopus sp.		
25	Elodea canadensis	55	Sphagnum cuspidatum		
26	Vallisneria americana	56	Sphagnum subsecundum contortum		
27	Eleocharis acicularis	57	Sphagnum fimbriatum		
28	Eleocharis Robinsii	58	Sphagnum majus		
29	Eriocaulon septangulare	59	Sphagnum papillosum		
30	Pontederia cordata	60	Sphagnum pylaesii		

TABLE 7
(cont'd.)

RESULTS OF THE DECORANA SPECIES ORDINATION

AXIS 1			AXIS 2			AXIS 3		
Species No.	Species	Axis Score	Species No.	Species	Axis Score	Species No.	Species	Axis Score
57	SPHA FIMB	20	44	MYRI OTEN	82	65	CALL GIGA	12
3	NITA FLEX	17	11	POTA CAPI	79	62	CKAD FKYU	3
68	HYGR TEXA	12	37	NYMP ODOR	71	46	UTRI CORN	2
63	FISS FONT	11	12	POTA CONE	68	64	POHL NUTA	-3
15	POTA NATA	9	10	POTA BERC	65	68	HYGR TEXA	-3
37	NYMP ODOR	9	16	POTA OAKS	64	47	UTRI GIBA	-7
46	UTRI CORN	8	35	ERAS SCHR	58	54	LYCO PUSP	-11
47	UTRI GIBA	-6	59	SPHA PAPI	56	33	POLY AMPH	-14
70	FONT HYPN	-6	28	ELFO ROBI	47	25	ELOD CANA	-16
42	MYRI OFAR	-7	52	UTRI VULG	32	50	UTRI PURP	-19
65	CALL GIGA	-9	45	NYMP CORD	31	40	ELAT MINI	-26
26	VALL AMER	-11	72	CLAD FLUI	11	44	MYRI OTEN	-30
11	POTA CAPI	-12	48	UTRI INTE	2	48	UTRI INTE	-37
6	NITA TENN	-18	47	UTRI GIBA	-16	70	FONT HYPN	-39
10	POTA BERC	-20	66	DREP ASPP	-17	11	POTA CAPI	-44
14	POTA FOLI	-27	49	UTRI MNOR	-23	24	SAGI TSPP	-45
5	NITA GRAC	-28	58	SPHA MAJU	-23	55	SPHA CUSP	-64
38	RANU REPT	-34	67	EURH RIPA	-23	10	POTA BERC	-74
21	POTA SPIR	-43	74	GYMN IFLA	-23	28	ELEO ROBI	-84
48	UTRI INTE	-49	3	NITA FLEX	-24	12	POTA CONE	-96
33	POLY AMPH	-52	15	POTA NATA	-24	19	POTA RICH	-99
4	NITA FURC	-72	1	CHAR ASPP	-25	21	POTA SPIR	-99
23	NAJA FLEX	-108	9	POTA AMPL	-25	34	CERA DEME	-99
22	POTA VASE	-134	17	POTA OBTU	-25	41	MYRI OALT	-99
39	CALL ISPP	-134	55	SPHA CUSP	-27	43	MYRI OHET	-99
25	FLOD CANA	-142	21	POTA SPIR	-34	45	NYMP CORD	-101
19	POTA RICH	-150	57	SPHA FIMB	-42	42	MYRI OFAR	-114
34	CERA DEME	-150	14	POTA FOLI	-44	66	DREP ASPP	-114
41	MYRI OALT	-150	42	MYRI OFAR	-48	38	RANU REPT	-129
43	MYRI OHET	-150	33	POLY AMPH	-55	14	POTA FOLI	-152
20	POTA ROBI	-174	19	FOTA RICH	-58	62	SPHA TERE	-229
1	CHAR ASPP	-182	34	CERA DEME	-58	60	SPHA PYLA	-387
9	POTA AMPL	-182	41	NYRI OALT	-58	61	SPHA RECU	-387
17	POTA OBTU	-182	43	MYRI OHET	-58	58	SPHA MAJU	-426
2	NITA ACUS	-214	46	UTRI CORN	-159	74	GYMN IFLA	-426

TABLE 8: Results of the Decorana Species Ordination. Species No. in Table 7.

AXIS 1		AXIS 2		AXIS 3	
Species No.	Axis Score	Species No.	Axis Score	Species No.	Axis Score
72	495	22	527	49	459
64	464	39	527	67	459
8	313	4	440	3	251
73	305	20	403	63	244
66	286	25	363	57	238
32	277	70	357	71	227
27	256	65	354	15	226
24	224	38	337	2	220
36	143	23	331	5	218
54	128	40	326	59	218
69	126	68	317	18	216
44	122	6	312	20	203
52	120	24	300	16	197
29	117	26	298	56	180
12	107	60	289	35	178
62	90	61	289	69	175
56	88	62	288	22	163
49	80	7	279	39	163
67	80	71	259	23	152
45	76	5	251	30	150
30	53	51	245	29	134
71	53	18	240	53	134
18	51	69	239	37	131
7	49	73	230	8	122
13	46	32	224	7	118
60	45	30	202	13	118
61	45	50	202	27	112
59	43	27	186	32	108
35	42	13	180	6	93
31	38	56	142	4	82
28	37	64	139	52	80
50	37	53	135	73	45
53	34	31	134	51	34
51	32	29	127	36	30
16	28	36	119	1	28
40	28	8	108	9	28
55	25	2	97	17	28
58	22	63	92	26	16
74	22	54	83	31	15
57	20	44	82	65	12
3	17	11	79	62	3
68	12	37	71	46	2
63	11	12	68	64	-3
15	9	10	65	68	-3
37	9	16	64	47	-7
46	8	35	58	54	-11
47	-6	59	56	33	-14
70	-6	28	47	25	-16

TABLE 8: (cont'd.) Results of the Decorana Species Ordination. Species No. in Table 7.

AXIS 1		AXIS 2		AXIS 3	
Species No.	Axis Score	Species No.	Axis Score	Species No.	Axis Score
42	-7	52	32	50	-19
65	-9	45	31	40	-26
26	-11	72	11	44	-30
11	-12	48	2	48	-37
6	-18	47	-16	70	-39
10	-20	66	-17	11	-44
14	-27	49	-23	24	-45
5	-28	58	-23	55	-64
38	-34	67	-23	10	-74
21	-43	74	-23	28	-84
48	-49	3	-24	12	-96
33	-52	15	-24	19	-99
4	-72	1	-25	21	-99
23	-108	9	-25	34	-99
22	-134	17	-25	41	-99
39	-134	55	-27	43	-99
25	-142	21	-34	45	-101
19	-150	57	-42	42	-114
34	-150	14	-44	66	-114
41	-150	42	-48	38	-129
43	-150	33	-55	14	-152
20	-174	19	-58	62	-229
1	-182	34	-58	60	-387
9	-182	41	-58	61	-387
17	-182	43	-58	58	-426
2	-214	46	-159	74	-426

TABLE 9: The results of division 1 (Group *) in Twinspan analysis. "B" indicates a borderline lake. Indicator species are *P. nutans schimperii* (*1) and *E. septangulare* (*0).

Group*0			Group*1
Axe	G&G 21	Little Otter	G&G4
Bell	G&G 75	Lohi	G&G14
Brandy	G&G 904	McKay	G&G54
Carlyle	G&G 103	Middle (B)	
Chub	Gullfeather	Moot	
Cinder	Hannah	Nelson	
Clear	Harp	Otter	
Clearwater (B)	Healey	Plastic	
Crosson	Heney	Red Chalk	
Dickie	Hillman	Solitaire	
Fawn	Horn	Swan	
Freeland	Kramer	Terry	
Frood	Leech	Labelle	
George	Leonard		
G&G 8 (B)	Little Clear		

TABLE 10: Preferential occurrence of species in groups produced by division 1 in Twinspan analyses. Values are percent occurrence within groups. Species codes as in Table 7.

Species Code	% Occurrence in Group		Group Preference
	*0	*1	
3	20	0	*0
6	23	0	*0
7	69	0	*0
12	20	0	*0
13	65	0	*0
15	37	0	*0
16	23	0	*0
28	25	0	*0
29	90	0	*0
30	69	0	*0
31	46	0	*0
35	53	0	*0
37	62	0	*0
40	27	0	*0
44	55	0	*0
45	20	0	*0
50	51	0	*0
51	48	0	*0
52	67	0	*0
53	62	0	*0
54	55	0	*0
55	23	0	*0
56	41	0	*0
69	60	0	*0
64	2	100	*1
72	2	23	*1
8	65	66	none
24	39	33	none
27	83	66	none
32	62	66	none
36	65	33	none
66	27	33	none

TABLE 11: The results of division 21 (group *0) in Twinspan Analysis. "B" & "M" indicate borderline and mis-classified lakes, respectively. Indicator species for group *01 were *Sparganium* sp., *P. epihydrous*, *N. odorata* and *B. Shreberi.*

Group*00		Group*01		
Brandy	(M)	Axe	Gullfeather	
Clearwater		Bell	Harp	
G&G8		Carlyle	Healy	
G&G21		Chub	Heeney	
Hannah		Cinder	Hillman	
Kramer	(B)	Clear	Horn	
Little Otter	(M)	Crosson	Leech	(B)
Lohi		Dickie	Leonard	
Middle		Fawn	Little Clear	(B)
Nelson		Freeland	McKay	
Solitaire		Frood	Moot	
Swan		George	Otter	
Labelle		G&G75	Plastic	
		G&G94	Red Chalk	(B)
		G&G103	Terry	

[1] -Group *1 with only 3 members was too small to further subdivide.

TABLE 12: Preferential occurrence of species in groups produced by division 2 (group *0) in Twinspan Analysis. Values are percent occurrence in group. Species codes as in Table 7.

Species Code	% Occurrence in Group		Group Preference
	*00	*01	
46	23	3	*00
7	38	83	*01
8	7	89	*01
10	0	19	*01
11	0	19	*01
12	0	29	*01
13	15	86	*01
15	7	50	*01
16	0	33	*01
28	7	33	*01
30	23	89	*01
31	15	59	*01
35	7	73	*01
36	23	83	*01
37	23	79	*01
42	7	19	*01
44	23	69	*01
45	0	29	*01
47	0	19	*01
48	0	19	*01
50	7	69	*01
52	16	63	*01
53	30	76	*01
54	23	69	*01
55	7	29	*01
56	0	59	*01
66	15	33	*01
69	30	73	*01
3	15	23	none
6	15	26	none
24	53	33	none
26	15	19	none
27	76	86	none
29	76	96	none
32	69	59	none
40	23	29	none

FIGURE 1: Location of study lakes. Numerical lake codes correspond to lake names given in Table 1.

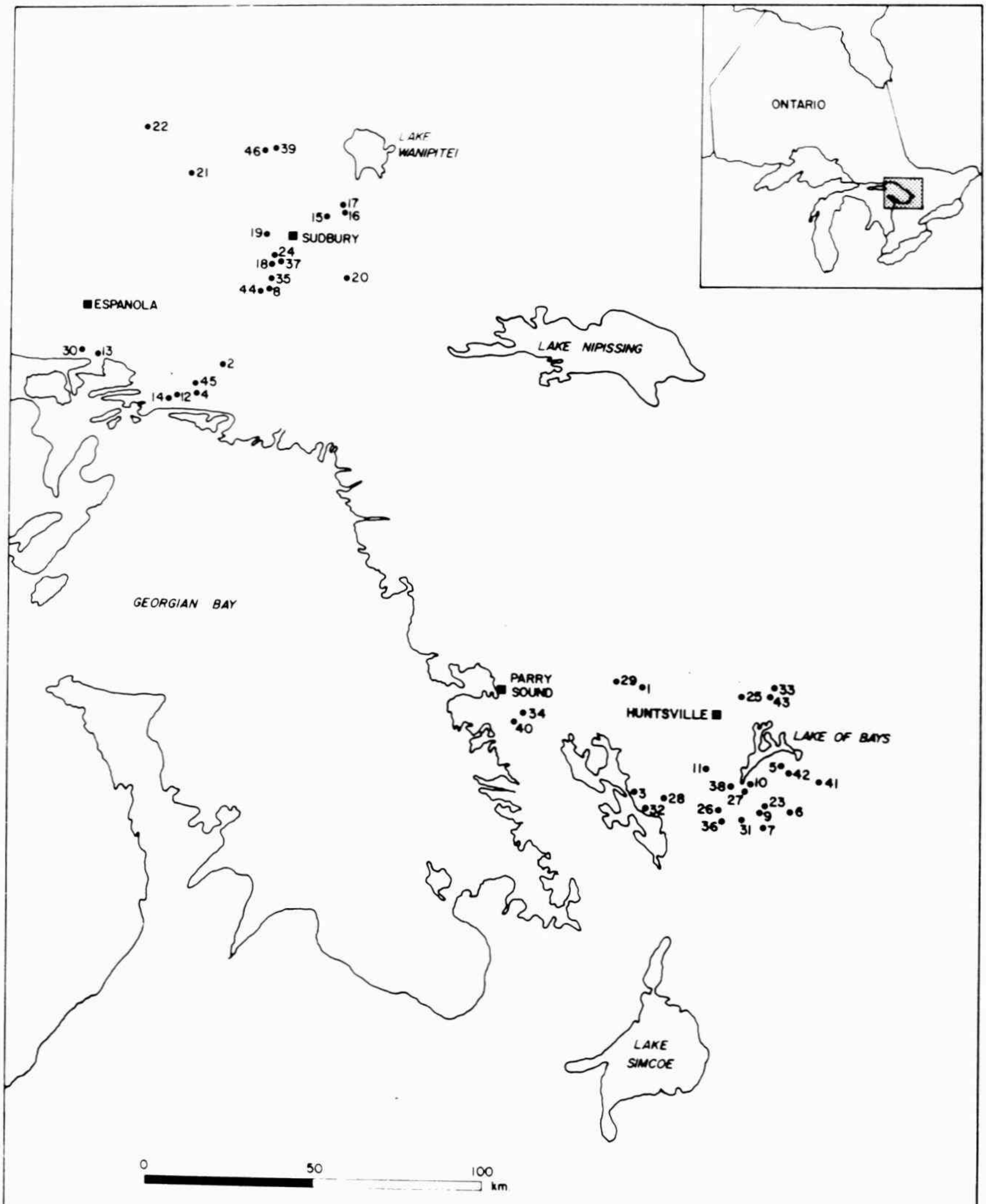
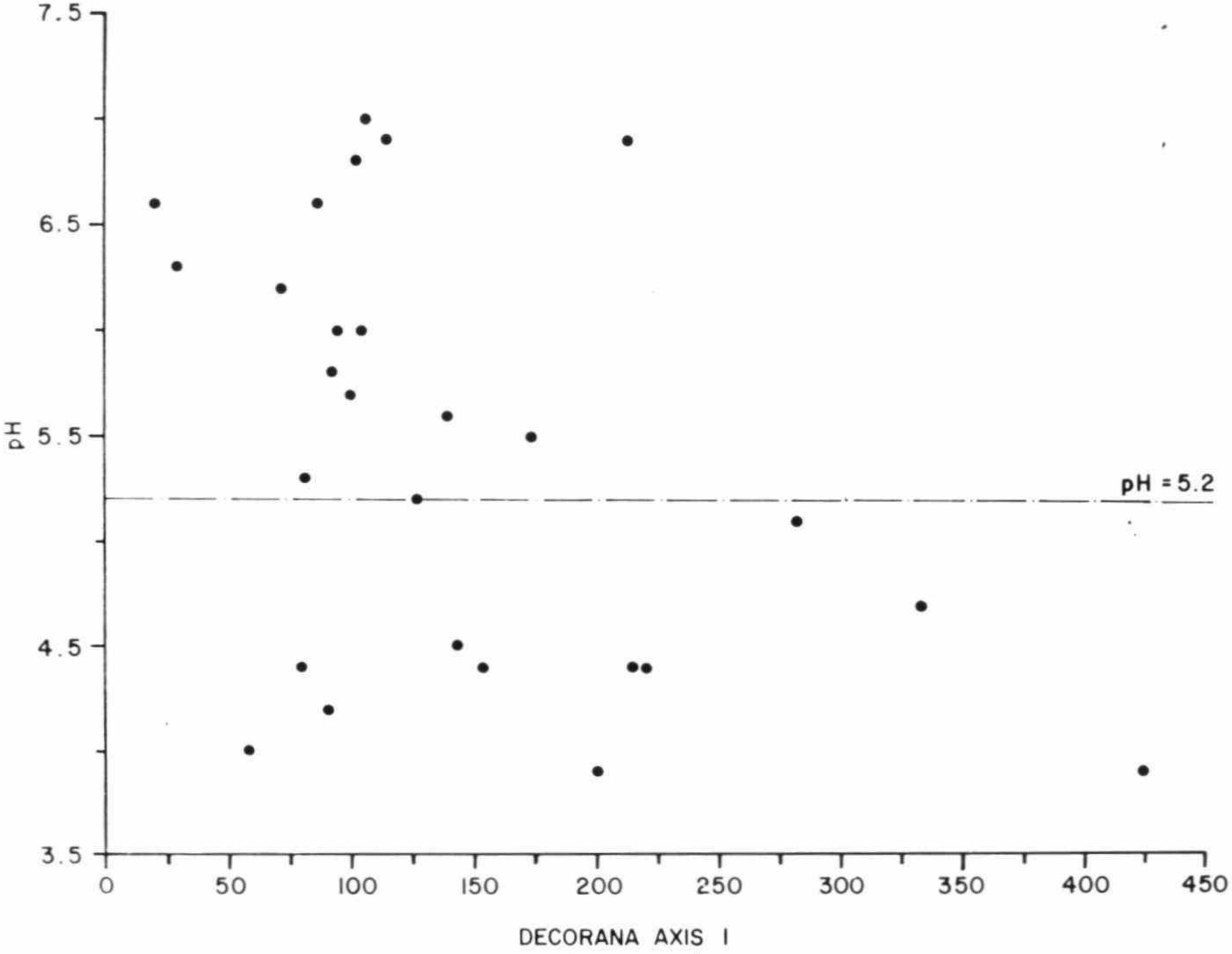


FIGURE 2: Plot of Lake pH Values and Ist Axis of DECORANA Analysis



QK
751
.W54
1983